PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

COMPOSIÇÃO, PROPRIEDADES E USO DE RECURSOS SECUNDÁRIOS COMO FERTILIZANTES ORGÂNICOS DE SOLOS

COMPOSITION, PROPERTIES, AND USE OF SECONDARY RESOURCES AS ORGANIC SOIL FERTILIZERS

СОСТАВ, СВОЙСТВА И ИСПОЛЬЗОВАНИЕ ВТОРИЧНЫХ РЕСУРСОВ В КАЧЕСТВЕ ОРГАНИЧЕСКИХ УДОБРЕНИЙ ПОЧВЫ

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RESUMO

O artigo discute as reservas de matérias-primas secundárias, fertilizantes orgânicos locais e ameliorantes (turfa, sapropel, fosfogesso, fosforitos, carvões de linhito, zeólitos, gipsita, calcário) na República do Bascortostão. O efeito do fosfogesso e do esterco de aves na fertilidade do solo e no rendimento da batata é estudado. O uso de gesso para melhorar o solo tem sido estudado e utilizado na agricultura e na restauração ambiental há muitos anos. A maior parte da literatura publicada é dedicada à influência do uso de gesso nas propriedades do solo e não no rendimento. O artigo apresenta os resultados de um experimento de campo sobre o uso de fosfogesso juntamente com resíduos de aves, com documentação detalhada de alterações na composição de microelementos dos solos, modo de precipitação e rendimento total após a fertilização. Os resultados do trabalho fornecido serão úteis na determinação das normas de aplicação de gesso; há também recomendações para pesquisas futuras sobre o uso de gesso para a melhoria do solo. A melhoria do rendimento pode ser o resultado de um efeito aditivo ou sinérgico; portanto, é altamente recomendável uma meta-análise de experimentos de gesso para melhorar as recomendações para o uso de gesso em vários ambientes. As taxas ideais de aplicação de matérias-primas secundárias são encontradas. O conteúdo do húmus do solo melhora e o rendimento da batata aumenta de 13,9 para 75,7 C/ha quando o fosfogesso é aplicado separadamente e em combinação com o esterco de aves. Existe o valor nutricional do esterco de aves, com os principais elementos como nitrogênio, fósforo e potássio. O fosfogesso é caracterizado com alto teor de estrôncio (14691 mg/kg) e elementos de terras raras (cério - 1358 mg/kg, praseodímio - 123,9 mg/kg, neodímio - 418,5 mg/kg, samário - 77,5 mg/kg, európio - 19,9 mg/kg, gadolínio - 58,9 mg/kg, térbio - 6,91 mg/kg e disprósio - 25 mg/kg). O conteúdo das formas totais de elementos no fosfogesso foi determinado por espectrometria de massa por plasma acoplado indutivamente (ICP-MS) usando um espectrômetro de massa VG Plasma Quad e Elan-6100.

Palavras-chave: *fertilizante; Agricultura orgânica; fosfogesso; estrume de aves; produtividade.*

ABSTRACT

The paper discusses reserves of secondary raw materials, local organic fertilizers, and ameliorants (peat, sapropel, phosphogypsum, phosphorites, lignite coals, zeolites, gypsum, limestone) in the Republic of Bashkortostan. The effect of phosphogypsum and poultry manure on soil fertility and potato yields is studied. The use of gypsum to improve soil has been studied and used in agriculture and environmental restoration for many years. Most of the published literature is devoted to the influence of the use of gypsum on soil properties and not on yield. The paper presents the results of a field experiment on the use of phosphogypsum together with poultry waste, with detailed documentation of changes in the microelement composition of soils, the mode of precipitation, and the total yield after fertilizing. The results of the given work will be useful in determining gypsum application norms; there are also recommendations for future research on the use of gypsum for soil improvement. The yield improvement may be the result of an additive or synergistic effect; therefore, a meta-analysis of gypsum experiments is strongly recommended to improve recommendations for the use of gypsum in various environments. The optimal application rates of secondary raw materials are found. The soil humus

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content improves, and potato yield increases from 13.9 to 75.7 C/ha when phosphogypsum is applied separately and in combination with poultry litter. There is the nutritional value of the poultry manure, with the main elements as nitrogen, phosphorus, and potassium. Phosphogypsum is characterized with high content of strontium (14691 mg/kg) and rare earth elements (cerium – 1358 mg/kg, praseodymium – 123.9 mg/kg, neodymium – 418.5 mg/kg, samarium – 77.5 mg/kg, europium – 19.9 mg/kg, gadolinium – 58.9 mg/kg, terbium – 6.91 mg/kg and dysprosium – 25 mg/kg). The content of total element forms in phosphogypsum was determined by inductively coupled plasma mass spectrometry (IPC-MS) using a VG Plasma Quad and Elan-6100 mass spectrometer.

Keywords: *fertilizer; organic agriculture; phosphogypsum; poultry manure; productivity*.

АННОТАЦИЯ

В статье рассматриваются запасы вторичного сырья, местных органических удобрений и мелиорантов (торф, сапропель, фосфогипс, фосфориты, лигнитные угли, цеолиты, гипс, известняк) в Республике Башкортостан. Изучено влияние фосфогипса и птичьего помета на плодородие почвы и урожайность картофеля. Использование гипса для улучшения почвы изучалось и использовалось в сельском хозяйстве и восстановлении окружающей среды в течение многих лет. Большая часть опубликованной литературы посвящена влиянию использования гипса на свойства почвы, а не на урожайность. Мы предлагаем результаты полевого эксперимента по использованию фосфогипса вместе с отходами птицеводства с результатами изменения микроэлементного состава почв, количества осадков и урожая после внесения удобрений. Результаты нашей работы будут полезны при определении норм применения гипса и использованию гипса для улучшения почвы. Повышение урожайности в наших исследованиях может быть результатом аддитивного или синергетического эффекта, поэтому перед применением фосфогипса в различных средах рекомендуется предварительный его метаанализ. Найдены оптимальные нормы внесения вторичного сырья. Содержание гумуса в почве улучшается, а урожай картофеля увеличивается с 13,9 до 75,7 ц / га при применении фосфогипса отдельно и в сочетании с птичьим пометом. Существует питательная ценность птичьего помета с основными элементами, такими как азот, фосфор и калий. Фосфогипс характеризуется высоким содержанием стронция (14691 мг/кг) и редкоземельных элементов (церия - 1358 мг/кг, празеодима - 123,9 мг / кг, неодима - 418,5 мг/кг, самария - 77,5 мг/кг, европия - 19,9 мг/кг, гадолиний - 58,9 мг/кг, тербий - 6,91 мг/кг и диспрозий - 25 мг/кг). Общее содержание элементов в фосфогипсе было определено с помощью масс-спектрометрии с индукционной плазмой используя спектометры VG Plasma Quad и Elan-6100.

Ключевые слова: *удобрение; органическое земледелие; фосфогипс; птичий помет; урожайность*.

1. INTRODUCTION

Soil is a living substance with a sanitary ecological function being one of the most important (Dobrovolsky and Grishina, 1985). The soil can process a large amount of foreign materials and convert them into humus substances useful to restore fertility. The soil systems are more adapted to process organic substances of animal and plant origin (droppings of wild birds, animals) into stable organomineral humus compounds due to their enzymatic mechanisms developed during the evolution (Nasir *et al.,* 2019; Szajdak and Simakina, 2008). However, this does not work the same for mineral fertilizers (Kiryushin, 2012; Willer and Kilcher, 2011).

The distinctive features of current farming systems are the prevention of soil degradation and the reduction of the risk of environmental violations in the production of agricultural products (Gabassova *et al.,* 2017; Khamaletdinov *et al.*, 2018; Surekha *et al.,* 2013). Improved environmental performance of agriculture requires bringing it in line with the laws of fertility, addressing the issues of biodiversity conservation, adaptation to agroecological conditions, optimizing the ratio of natural and agricultural lands, creating an optimal infrastructure of agricultural landscapes taking into account energy and mass transfer (Kiryushin, 2012; Willer and Kilcher, 2011). It has now become evident that natural, biological technologies are the alternative to the chemical load on agriculture (Gelashvili *et al.,* 2002). Biotechnology uses the ability of microorganisms, worms, cell cultures, tissues, their constituent parts to synthesize compounds important for humans (Gukalov, 2009). At the same time, the soil accumulates carbon, nitrogen, potassium, phosphorus, and microelements, getting better regime and structure and less effect of toxic substances (Kiryushin, 2012, 2015). Biotechnologies can restore soil fertility as well as its productivity as a result of lower pesticide load, higher plant resistance to adverse environmental conditions (Khaibullin *et al.*, 2018; Sokolov, 1975).

Organic farming is a system that uses organic sources to feed crops and biological sources to control pests and diseases. Biofertilizers are also essential components of organic farming. They stimulate plant growth, biological restoration of the soil and its natural fertility, protect against drought, and some plant diseases. Composting can play an essential role in solid waste management programs and can significantly reduce the amount of wastes in a landfill. Moreover, it saves resources and reduces soil pollution (Pathak, 2011; Surekha *et al.,* 2013).

The growing interest in more significant organic farming and agricultural production is due to the constant increase in prices for agrochemicals and energy sources, low utilization of mineral fertilizers by plants, significant soil nutrient losses, decreased product quality with intensive use of mineral fertilizers and pesticides. The total number of farms introducing biological methods of agriculture is growing by about 8,9% per year. Their area has grown from 15.8 million hectares to 37.2 million hectares worldwide over the past decade (Paull, 2011; Wai, 2007; Willer and Kilcher, 2011).

The soil can process significant amounts of foreign material into stable organomineral humus compounds to restore and improve the fertility of leached Chernozem and increase the productivity of cultivated crops. The need to develop effective methods of soil fertility recovery to create optimal conditions and increase the agricultural biocenoses productivity underlies the importance of this direction.

The goal of this work is to assess the efficiency in using secondary resources (wastes of the poultry industry and the production of mineral fertilizers) as the primary sources of organic substances and nutrients entering the soil.

2. MATERIAL AND METHODS

2.1. Experimental site

The experimental work was carried out by stationary field and laboratory-analytical methods. Stationary field studies were conducted on leached Chernozem (*Luvic Chernozems*) in the southern forest-steppe zone during the plantation of the Nevsky potatoe variety in 2015-2017. Mainly, it was the experimental field of the Educational and scientific center of the Bashkir State Agrarian University, Russia. The sections of the field experiment had a width of 4–5, a length of 8–9 m, and a slope of 1–3°. A topographic survey (scale 1:100) in the international coordinate system (WGS) -84) and the Baltic elevation system with an interval between the contours of 0.1 m was performed to obtain more fundamental characteristics of the plots. The plots were leveled, equipped with sewage and water intake, bordered around the perimeter and separated from each other by earthen walls; On the arable land, plowing of slabs to a depth of 20 cm was practiced; the original vegetation cover of the deposit consisted of purple alfalfa (*Medicago sativa*) and meadow and weed plants: reeds (*Anthemisarvensis*), milk thistle (*Sonchus arvensis*), common wormwood (*Artemisia absinthium L.*) and field bindweed (*Convolvulus arven L.*). The soil was suitable for weakly leached and weakly weathered clay-clay-illuvial arable chernozem (*Luvic Chernozem (Clayic, Aric, Pachic)*. It was characterized by medium-deep humus horizons (AU + AUb 60 cm), average humus content, and slightly acid reaction. The aggregate state and porosity of the plow layer were evaluated as ideal; The water-resistance of the soil structure was high. The total amount of irrigation water was determined using rain gauges (5 sensors) installed around the periphery of the studied areas.

2.2. Sampling

The water permeability of the soil was determined by the cylindrical method (Vadiunina & Korchagina, 1986). Soil samples for determining the structural-aggregate composition and density were taken in layers of 0–10 and 10–20 cm in four repetitions. Samples were taken before, and after irrigation, soil moisture in the upper layer between irrigation was 15–20%, air temperature 20–25 °C; wind speed did not exceed 2 m/s.

2.3. Fertilizer application

After moldboard plowing and secondary tillage (harrowing), two plots of 0,1 hectares each were selected. The experiment scheme included a traditional farming system and variants to improve soil fertility: 1- control (without application); 2- Phosphogypsum, 5 t/ha; 3- Phosphogypsum, 10 t/ha; 4- Phosphogypsum, 20 t/ha; 5- poultry manure, 40 t/ha; 6-

Phosphogypsum+poultry manure, 1:10 ratio of 1:10, dose 40 t/ha.

2.4. Laboratory analytical methods

Soil samples were selected based on the upper genetic horizons of the soil profile, laboratory and analytical studies were carried out using methods accepted in soil science. The total humus was determined by the method of I. V. Tyurin, soil moisture, and macronutrients (nitrogen, phosphorus, potassium) were detected according to the available guidelines for agrochemical indicators (Arinushkina, 1970; Vadiunina and Korchagina, 1986).

The content of total element forms in phosphogypsum was determined by mass spectrometry with inductively coupled plasma-ICP-MS on a VG Plasma Quad and Elan-6100 mass spectrometer under standard change conditions using imported reference samples in the laboratory of the Federal State Unitary Enterprise "All-Russian Research Institute of mineral raw materials named after N. M. Fedorovsky". The measurement error at the level of units and hundredths is no more than 15%. The device was calibrated with standard solutions containing a set of appropriate elements. The element concentration was based on the following: the analyzed solution was sprayed, the flow of argon brings it into a high-temperature plasma, where most of the atoms are ionized. Some of the ions formed in the plasma fall into a vacuum chamber, where they were accelerated and focused using ion lenses. Then the ion beam enters the inhomogeneous electromagnetic field of the quadrupole, where ions are spatially separated by weight. When scanning the electromagnetic field of the quadrupole, ions of a certain weight fell sequentially on the ion detector and were registered using electrical measuring devices. The received signals were proportional to the content of certain ions in the plasma, were processed using a computer system, and the analyses results were printed out.

Statistical processing of experimental data was performed using Microsoft Office Excel 2007 and SNEDECOR V. 5.80 software.

3. RESULTS AND DISCUSSION

Due to the sharp disparity in prices for agricultural products, and material costs for its production, the use of mineral fertilizers is sharply limited at present. There is much concern about the reproduction of soil fertility. Having conducted an analytical analysis of the possible economically and environmentally beneficial ways to reproduce soil fertility, we figured it to be possible to use the available resources, which the Republic of Bashkortostan possesses.

Stocks of the secondary material resources, local organic fertilizers, and ameliorants are huge, but they are not used to the full (Khabirov, 2015). Some of them are practically not used (Table 1).

The Meleuz plant of mineral fertilizers has 11 million tons of phosphogypsum, which is practically not used. Phosphogypsum stacks occupy a large area and are a danger to the local ecological situation, although phosphogypsum is a valuable multi-component fertilizer. It is not actually applied to the soils of the Republic of Bashkortostan since there are no enough recommendations for its use. Poultry farms of the Republic of Bashkortostan collect hundreds of thousands of tons of poultry manure every year. For example, in storage facilities of the Poultry Production unit named after M. Gafuri, there about 500 thousand tons of high-quality turkey manure. We have taken the first steps to develop complex multi-component organic and mineral fertilizers based on phosphogypsum, and turkey manure, since the sources of raw materials are close to each other.

At the site where raw poultry manure of the M. Gafuri Poultry Production unit is stored, there is an unpleasant stinking smell. The manure mass contains much weed seeds, eggs and larvae of worms and flies, and a lot of microorganisms. Long-distance transportation of manure is not economically justified and requires a lot of equipment, labor, and money. However, waste is usually concentrated in small areas, which exacerbates its negative effect. As a result, the components of ecosystems located in the zone of large poultry farms are significantly transformed (Kiryushin, 2012; Gabassova *et al.,* 2017).

Manure processing can be a reasonable solution to this situation. In particular, high-temperature drying turns manure into a decontaminated, highly concentrated fast-acting organic fertilizer with favorable physical properties, devoid of smell, and germinating weed seeds. The value and nutritional properties of dry manure will be determined by the chemical composition of the raw materials taken for processing (the original raw manure) and the drying technology. However, before recommending the final product (dry manure) for use as a fertilizer, it is necessary to determine its potential fertilizing properties and assess its safety for environmental components.

The nutritional value of manure, like any other fertilizer, is determined by the content of the main elements of plant nutrition as nitrogen, phosphorus, and potassium (Table 2).

The nitrogen content in the manure taken for processing is low. One ton of this organic fertilizer can introduce just 6.3 kg of nitrogen into the soil. It is due to both the high moisture content of the source material and the relatively low concentration of the element per dry substance. As a rule, the nitrogen content is reduced during the drying process for its ammonia form that rapidly evaporates under thermal action.

Poultry manure is evenly applied to the fallow once per crop rotation with further placement to accelerate the transformation process.

Such important plant nutrition elements as calcium, phosphorus, and sulfur make phosphogypsum an attractive fertilizer (Davari *et al.,2002*). Currently, the average level of the nutritive efficiency of this industrial waste is no more than 2.0 %, although in previous years it was about 2.5 million tons/year (over 10% of the current output) In agricultural production phosphogypsum can be used for the following purposes:

- for improving physical soil properties;

- for the optimization of plant nutrition with calcium, sulfur, silicon, phosphorus and trace elements;

- for soil reclamation (Tayibi *et al.,2009*).

For Chernozem soils, the use of phosphogypsum is even more in demand, since the content of phosphorus is one of the main limiting factors.

According to literature data, recommended doses of phosphogypsum vary from 2 to 35 t / ha depending on the type of soil, crops to be grown, method and type (continuous or selective) of application and fertilizers to be used (Kotova *et al.,2002*)

The analysis of phosphogypsum (waste from the Meleuz mineral plant) shows a high content of strontium (14691 mg/kg) and rare earth elements (cerium-1358 mg/kg, praseodymium – 123.9 mg/kg, neodymium – 418.5 mg/kg, samarium – 77.5 mg/kg, europium – 19.9 mg/kg, gadolinium – 58.9 mg/kg, terbium- 6.91 mg/kg and dysprosium 25 mg/kg), which is not typical for soils and rocks of the southern Urals. The content of oxides in phosphogypsum is shown in Table 3.

Taking into account the chemical composition of phosphogypsum, its direct and indirect influence on soil fertility, the following experimental scheme was developed:

-control

- phosphogypsum, 5 t / ha;

- phosphogypsum, 10 t / ha;

- phosphogypsum, 20 t / ha;

- poultry manure, 40 t / ha;

- phosphogypsum+poultry manure, 1:10 (40 t/ha)

Based on the current situation, a sharp decrease in the content of organic matter in the soil, the paper presents the content of humus.

When conducting experimental research, there were changes in the humus state of the soil. When applying pure phosphogypsum, there was no significant effect on the content of humus in the soil. However, when applying it together with poultry manure, there was an increase in the humus content by 0.34%. Maximum values of 7.02-7.10 % were observed when applying pure poultry manure at a dose of 40 t / ha (Table 4).

Potatoes of the Nevsky variety were grown on the experimental plots for three years. In the first year of studies, the maximum increase (307C/ha) was observed in the variants with 40 T/ha of introduced poultry manure. The use of phosphogypsum in pure form also increased from 22.2 to 91.7 C/ha with higher rates of application (Table 5). There was a higher yield at 137 C/ha in the variant with applied manure and phosphogypsum compared to the control one. As scientists claim (Baibekov *et al.,* 2012; Belyuchenko and Muravyov, 2009), at the phosphogypsum application rate of 5 t/ha, 100-130 kg of P_2O_5 in digestible form can enter the soil. It covers the costs of agriculture significantly for phosphogypsum transportation and introduction.

The second year of research (2016) was dry, and the soil moisture content was 140 mm. It affected the yield of potatoes. The yield development by variants remained in the same sequence as the first year of research (Zinkovskaya, 2010). It is established that the phosphogypsum application at the rate of 2-4

C/ha can meet the needs of agricultural plants in nutrients and increase crop yields.

In 2017, the largest increase was observed on the variants with pure poultry manure and in a mixture with phosphogypsum, 75.7, and 63.2, respectively. The aftereffect of phosphogypsum provided a significant increase in all years of research. The application of a higher rate of phosphogypsum resulted in lower potato yield. A negative impact on the growth and development of plants led to potato inhibition. There were no toxic metals and nitrates in potato tubers in examining.

The current scientific papers provide similar ways to improve the agrochemical qualities of the soil, neutralize the reaction of the soil solution medium (Pavani and Shanmugam, 2019). Alternatively, to suppress the intake of heavy metal salts in plants (Sattar *et al.,* 2019).

However, an approach comparable to ours, involving the simultaneous synergistic use of phosphate gypsum with poultry waste, is relatively rare (Xue *et al.,* 2020).

Also, more often the mechanism of the positive effect on the crop is not appropriately discussed, and it is difficult to translate the improvement of individual soil qualities in connection with the improvement of the yield, despite the obviousness of this connection, the fact is that it is difficult to accurately determine the positive effects of the use of gypsum, which are responsible for the increase in yield because in the soil there are often many simultaneous physical and chemical changes. Improving yields may result from the additive or synergistic effect of each of these potential changes. Besides, these potential changes, no matter how different they may seem, also differ depending on the crop, soil type, and precipitation regime (Zoca and Penn, 2017).

Taking into account the chemical composition of phosphogypsum, research variants with different application rates, climatic conditions for three years provide reliable data on their impact on crop yields.

The problem of heavy metals in soils is relevant for agriculture, scientists Santos *et al.* (2006), Davari *et al.* (2012), Alloway (1990), and Mineev (1990) point out the possible accumulation of toxic metals in the soil as a result of the phosphogypsum application. Nevertheless, the authors found no significant changes in the natural levels of heavy metals if ameliorant is introduced at recommended rates directly after the phosphogypsum application as well as in long biogeosystem sequences. Moreover, it was shown in the work of Sattar *et al.* (2019) that the use of gypsum together with poultry waste could contribute to the reduction of heavy metals in agricultural products, even at high levels of heavy metal charging of the original soils (before the application of gypsum and poultry waste).

In addition, the essential role of phosphogypsum as a fertilizer is that it has other macro and microelements in its composition. When applied to the soil in small rates, it does not have a harmful effect and, therefore, can serve as a mineral supplement (Bauer *et al.,* 2019). Another component of the fertilizer offered by the authors is poultry waste, having been widely used as a fertilizer, the subject of many papers for a long time (Szogi *et al.,* 2019). Thus, the first results of studies have shown the phosphogypsum efficiency applied both separately and in a mixture with poultry manure.

4. CONCLUSIONS

The application of phosphogypsum and poultry droppings in pure form and a mixture is characterized by environmental safety. There is a high potential fertilizing value and expediency of applying secondary resources as organic fertilizers. When applied to the soil in all ratios and rates, phosphogypsum and poultry manure improve the humus state, significantly increase the yield of potatoes from 13.9 to 75.7 C/ha. Meanwhile, potatoes do not contain toxic elements and nitrates exceeding the MPC values.

REFERENCES

1. Alloway, B. J. Y. (1990). *Heavy metals in Soils.* New York: Wiley and Sons.
2. Arinushkina, E. V. (1970). *Guide to chemical analysis of soils.* Moscow: Moscow State University Publ.
3. Baibekov, R. F.; Shilnikov, I. A.; Akanova, N. I.; Dobrydnev, E. P.; Loktionov, M. Yu.; Sheujen, A. Kh.; Kizinyok, C. B. (2012). *Scientific and practical recommendations for using phosphogypsum neutralized as a chemical ameliorant and sulfur fertilizer.* Moscow: VNIIA Publ.
4. Bauer, P. J.; Szogi, A. A.; Shumaker, P. D. (2019). Fertilizer efficacy of poultry litter ash blended with lime or gypsum as fillers. *Environments*, 6, 50.

5. Belyuchenko, I. S.; Muravyov, E. I. (2009). Influence of industrial and agricultural wastes on physical and chemical properties of soils. *Ecological Bulletin of Northern Caucasus*, 5, 84.
6. Vadiunina, A. F.; Korchagina, Z. A. (1986). Methods to study physical properties of the soil. Moscow: Agropromizdat Publ.
7. Davari, M.; Sharma, S. N.; Mirzakhani, M. (2012). The effect of combinations of organic materials and biofertilisers on productivity, grain quality, nutrient uptake and economics in organic farming of wheat. *Journal of Organic Systems,* 7(2), 26-35
8. Dobrovolsky, G. V.; Grishina, L. A. (1985). *Conservation of soil.* Moscow: Moscow State University Publ.
9. Gabassova, I. M.; Suleymanov, A. R.; Garipov, T. T.; Sidorova, L. V.; Sayfullin, I. Yu.; Suleymanov, A. R. (2017). Assessment of slope soil suitability for irrigation in the Northern forest-steppe of Bashkortostan. *Agrarian Russia,* 5, 2-7
10. Gelashvili, D. B.; Basurov, V. A.; Efimova, N. I. (2002). Ecological and economic analysis of environmental hazards of enterprises in the agro-industrial complex. Ecological and economic bases to develop agrobiogeocenoses. *Nizhnii Novgorod,* 1, 31-35.
11. Gukalov, V. V. (2009). Influence of phosphogypsum on winter wheat growth and productivity. In *The I All-Russian scientific conference. Issues on recultivation of household, industrial, and agricultural waste* (pp. 32-34). Krasnodar: Kuban State Agrarian University Publ.
12. Khabirov, I. K. (2015) The challenge of maintaining and improving soil fertility in the Republic of Bashkortostan. *Parliament proceedings, State Assembly Kurultai of the Republic of Bashkortostan,* 60-63.
13. Khaibullin, M. M.; Kirillova, G. B.; Yusupova, G. M.; Kagirov, E. S.; Ismagilov, R. Z.; Rakhimov, R. R.; Bagautdinov, F. Y. (2018). Influence of percentage fertilizer systems on change of agrochemical properties of the arable layer of leach Chernozem and on the crops productivity of crop rotation. *Journal of Engineering and Applied Sciences,* 13(S8), 6527-6532.
14. Khamaletdinov, R. R.; Gabitov, I. I.; Mudarisov, S. G.; Khasanov, E. R.; Negovora, A. V.; Martynov, V. M.; Shirokov, D. Y. (2018). Improvement in engineering design of machines for biological crop treatment with microbial products. *Journal of Engineering and Applied Sciences,* 13(S8), 6500-6504.
15. Kiryushin, V. I. (2012). Problem of agriculture ecologization in Russia (Belgorod model). *Achievements of Science and Technology in Agriculture,* 12, 3-9.
16. Kiryushin, V. I. (2015). Developing knowledge on landscape functions with reference to better landscape management. *Bulletin of the Soil Institute named after V.V. Dokuchaev,* 80, 16-25.
17. Kotova, L. G.; Pomazkina, L. V.; Repina, O. V.; Prokofiev, A. Yu. (2002).The effect of gray forest soil pollution with fluoride on the productivity and mineral nutrition of spring wheat. *Agrokhimiya (Agrochemistry), 12,* 31–36.
18. Mineev, V. G (1990). *Chemization of agriculture and the natural sphere.* Moscow: Agropromizdat Publ.
19. Nasir, B.; Rosmini, R.; Lasmini, S. A.; Wahyudi, I.; Edy, N. (2019). Combined application of mulches and organic fertilizers enhance shallot production in dryland. *Agronomy Research,* 17(1), 165-167.
20. Pathak, R. K. (2011). Homa jaivik Krishi: A ray of hope for sustainable horticulture MARDI's initiatives. In *National symposium cum brainstorming workshop on organic agriculture, CSKHPKV, Palampur, India held on April* (pp. 19-20).
21. Paull, J. (2011). The uptake of organic agriculture: A decade of worldwide development. *Journal of Social and Development Sciences,* 2(3), 111-120.
22. Pavani, K.; Shanmugam, P. M. (2019). Maximization of rice yield in sodic soil through combined application of gypsum and organic amendments. *Research on Crops, 20*(4), 676-684.
23. Santos, A. J. G.; Mazzilli, B. P.; Fávaro, D. I. T.; Silva, P. S. C. (2006). Partitioning of radionuclides and trace elements in phosphogypsum and its source materials based on sequential extraction methods. *Journal of Environmental Radioactivity,* 87(1), 52-61.
24. Sattar, H.; Anwar-ul-Haq, M.; Ahmad, H. R.; Jaskani, M. J. (2019). Immobilization of chromium by poultry manure and gypsum in soil and reducing its uptake by spinach grown with textile effluent irrigation. *Pakistan Journal of Agricultural Sciences,* 56(4), 791.
25. Sokolov, A. V. (1975). *Agrochemical methods of soil research.* Moscow: Nauka

Publ.
26. Surekha, K.; Rao, K. V.; Shobha Rani, N.; Latha, P. C.; Kumar, R. M. (2013). Evaluation of organic and conventional rice production systems for their productivity, profitability, grain quality and soil health. *Agrotechnology,* 11, 1-6.
27. Szajdak, G. S. L.; Simakina, I. (2008). Changes in the structure of nitrogen-containing compounds of peat-, sapropel-, and brown coal-based organic fertilizers. *Agronomy Research,* 6(1), 149-160.
28. Szogi, A. A.; Shumaker, P. D.; Ro, K. S.; Sigua, G. C. (2019). Nitrogen mineralization in a sandy soil amended with treated low-phosphorus broiler litter. *Environments,* 6(8), 96.
29. Tayibi, H.; Choura, M.; Lopez, F. A.; Alguacil, F. J.; Lopez Delgado, A. (2009). Environmental impact and management of phosphogypsum. Journal of Environmental Management, 90, 2377-2386.
30. Wai, K. O. (2007). Organic Asia. *The Organic Standard,* 71(3), 3-6.
31. Willer, H.; Kilcher, L. (2011). *The world of organic agriculture: statistics and emerging trends 2011:* Bonn: International Federation of Organic Agriculture Movements (IFOAM). Frick, Switzerland: Research Institute of Organic Agriculture (FiBL).
32. Xue, S.; Ke, W.; Zhu, F.; Ye, Y.; Liu, Z.; Fan, J.; Hartley, W. (2020). Effect of phosphogypsum and poultry manure on aggregate-associated alkaline characteristics in bauxite residue. J*ournal of Environmental Management,* 256, 109981.
33. Zinkovskaya, T. S. (2010). *Recultivation problems of household, industrial, and agricultural waste.* Krasnodar.
34. Zoca, S. M.; Penn, C. (2017). An important tool with no instruction manual: a review of gypsum use in agriculture. In *Advances in Agronomy* (Vol. 144, pp. 1-44). Academic Press.

Table 1. *Raw material resources of local fertilizers and ameliorants in the Republic of Bashkortostan*

Natural raw materials	Effect on physical and physico-chemical properties of soils	Application efficiency depending on the type of degradation	Reserves in the Republic of Bashkortostan, mln. t
Peat	Higher moisture capacity, porosity, absorption capacity, humus content, lower acidity	Physical (erosion), depletion, pollution, pyrogenesis	134.3
Phosphogypsum, phosphorites, including phosphates (peat vivianite, vivianite)	Higher phosphorus content, moisture capacity, absorption capacity, nitrogen content, microelements	Physical (erosion), depletion	15.5
Lignite coals	Higher moisture and absorption capacity, adsorbing ability	Pollution, salination	257.5
Sapropel	Higher content of humus, nitrogen, phosphorus, microelements, adsorbing ability, lower acidity	Physical (erosion), depletion, salination	no data
Zeolites	Higher moisture content, absorption capacity, adsorbing ability	Pollution, salination, drying	no data
Gypsum	Exchange sodium is replaced by calcium, and alkalinity is weakened	Alkalinization	84.1
Limestone	Neutralized acidity	Acidification, depletion	59.5

Table 2. *Characteristics of the nutritional value of poultry manure*

Manure type	Humidity, %	Content, % per crude substance		
		N	P2O5	K2O
Manure before drying	75	0.54	0.85	0.79
Requirements for dry manure	14	4.03	3.78	2.00
The average composition of the dry manure	no > 15	no < 2.0	no < 2.0	no < 0.8

Table 3. *Chemical composition of phosphogypsum*

Element	Content mg/kg	Element	Content mg/kg
Calcium oxide (CaO)	30.9	Sodium oxide (Na2O)	0.049
Iron oxide (Fe2O3)	0.091	The potassium oxide (K2O)	0.043
Titanium oxide (TiO2)	0.079	Magnesium oxide (MgO)	0.011
Aluminum oxide (Al2O3)	0.047		

Table 4. *Changes in the content of total humus in Chernozemic soil (black soil with high humus content)*

Name of experiments	Humus, %			
	2015	2016	2017	average
Control	6.64	6.61	6.60	6.61
Phosphogypsum, 5 t/ha	6.65	6.66	6.64	6.65
Phosphogypsum, 10 t/ha	6.81	6.82	6.72	6.78
Phosphogypsum, 20 t/ha	6.85	6.81	6.76	6.81
Poultry manure, 40 t/ha	7.08	7.10	7.02	7.07
Phosphogypsum + poultry litter, 1: 10 (40 t/ha)	6.97	7.02	6.94	6.98

Table 5. *Potato yield*

Experiment Variants	2015		2016		2017	
	Yield	Increase	Yield	Increase	Yield	Increase
	C/ha					
Control	113.0	-	98.9	-	74.3	-
Phosphogypsum, 5 t/ha	135.2	22.2	100.4	1.5	88.9	14.6
Phosphogypsum, 10 t/ha	140.3	27.3	102.2	3.3	91.0	16.7
Phosphogypsum, 20 t/ha	210.1	97.1	100.9	2.0	88.2	13.9
Poultry manure, 40 t/ha	420	307	150	51.1	150	75.7
Phosphogypsum + poultry litter, 1: 10 (40 t/ha)	250.0	137	132.5	33.6	137.5	63.2